PRELIMINARY REPORT ON THE USE OF AERIAL PHOTOGRAPHS IN FOREST INVENTORIES

PRESENTED TO
THIRD REGIONAL CARTOGRAPHIC CONFERENCE OF THE UNITED NATIONS
FOR ASIA AND THE FAR EAST
BANGKOK, 27 OCTOBER- 10 NOVEMBER 1961

IN SUPPORT OF
AGENDA ITEM 16 PHOTO-INTERPRETATION

BY
UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
WASHINGTON 25, D. C.

USE OF AERIAL PHOTOGRAPHS IN FOREST INVENTORIES

Adapted from a report to the Internation Union of Forest Research Organizations made by a committee listed at the end of this paper

Introduction

In 1959 a committee was formed under Section 25 of the International Union of Forest Research Organizations with the purpose of studying the use of aerial photographs in forest inventories and recommending standard applications and further research in techniques. This paper covers part of the progress report made by that committee in September, 1961 to the 13th Congress of the International Union of Forest Research Organizations in Vienna, Austria. It gives the committee's preliminary list of useful applications of aerial photography to forest inventories. Another part of the progress report gave a preliminary list of current research studies to increase the efficiency of applying aerial photography to forest inventories.

Preliminary List of Aerial Photo Applications to Forest Inventories

A - Aerial photographic techniques

1 - For compiling forest base maps (planimetric or topographic) photo scales of 1:30,000 to 1:50,000 taken with a focal length of 6 inches are generally preferred.

2 - For classification and mapping of such area classes as cover type, stand-volume, stand-size, crown closure and physiographic site, photo specifications vary with forest regions.

a - In temperate forests of North and Central America and Europe, stereoscopic vertical photography (with 60 percent forward lap and 30 percent sidelap) using panchromatic film and minus-blue filter, taken in summer (e.g., in North America May through September) within 2 or 3 hours of noon is generally used. A negative size of 9X9 inches, negative scale of approximately 1:15,840 to 1:20,000 and a focal length of $8\frac{1}{4}$ inches is also generally used.

b - In mixed Spruce-fir and Aspen-birch forests of North America, the application in "a" is sometimes varied by using an infra-red film and minus-blue filter (to give contrasts between softwoods and hardwoods and between well-drained and poorly-drained sites).

c - In western parts of North America (where tall timber and steep topography is common), application as in "a" is recommended but with use of a negative scale of about 1:12,000 to 1:14,400 and a 12-inch focal length (to avoid parallax of such proportions as to be annoying when viewing stereoscopic images of tall timber).

d - In Australia, application as in "a" is recommended, but with summer photography at a scale of 1:15,840 and focal lengths of 10 or 12 inches preferable. More care is also taken in orienting flights to avoid shadow point (hot spot)1/ 2/.

e - In Great Britain, application as in "a" has been used but with scales of 1:10,000 or 1:20,000 and focal length of 6 to 36 inches.

f - In Central Europe, application as in "a" has been used. A scale of photography of 1:10,000 is generally preferred and necessary where large-scale forest base maps (e.g., 1:5,000 or 1:2,500) are required.

g - In tropical regions (e.g. in India, Pakistan, Thailand, Ceylon, Malaya and parts of Africa), photos at scales between 1:30,000 and 1:50,000

1/ Sims, W. G. SHADOW POINT Leaflet 67. Forestry & Timber Bureau, Canberra A.C.T. 1954.

2/ Anon. THE AVOIDANCE OF "SHADOW POINT" ON AERIAL PHOTOGRAPHS. Leaflet 74, Forestry & Timber Bureau, Canberra A.C.T. 1955.

with focal lengths of 6 inches have been used, although limited coverage at 1:15,000 has been used. 3/ 4/ 5/ 6/

3 - For interpreting such details of forest or tree conditions as incidence of attacks by tree insects and diseases and for species identification in the United States, several photo specifications have been used.

a - Stereoscopic vertical color photography taken at a season varying with the incidence of the particular pest (generally summer) within 2 hours of noon is recommended generally. Negative sizes appreciably smaller than 9X9 inches and negative scales larger than approximately 1:8,000 (up to 1:1,000 or larger) are useful.

b - Black and white (generally panchromatic) vertical photography is useful but less so than color is.

c - Low-altitude oblique photography is also useful, particularly as a supplement to applications in "a" and "b".

B - Photo interpretation equipment and aids

1 - Direct vision stereoscopes are used most for interpreting general forest conditions. Greater use of scanning stereoscopes (such as the Old Delft) is recommended for detailed interpretation.

3/ DeRosayro, R. A. THE APPLICATION OF AERIAL PHOTOGRAPHY TO STOCK-MAPPING AND INVENTORIES ON AN ECOLOGICAL BASIS IN RAIN FOREST IN CEYLON. Empire Forestry Review, 38 (2) No. 96, June 1959.

4/ Francis, D. A. THE USE OF AERIAL PHOTOGRAPHY IN TROPICAL FORESTS. UNASYLVA, 11 (3), 1957.

5/ Loetsch, F. A FOREST INVENTORY IN THAILAND. UNASYLVA, 11 (4), 1957.

6/ Miller, R. G. THE USE OF AERIAL PHOTOGRAPHS IN FORESTRY IN BRITISH COLONIES. Paper to 7th British Commonwealth Forestry Conference, 1957.

2 - Aerial stand volume tables are used to some extent in Canada and the United States and are in more limited use in Australia as aids in stratifying forest by gross volume classes. Total measurable height and crown closure are generally recognized as the most useful variables in stand volume tables. For tropical rain forests the most useful tables may be those based only on crown closure.

3 - Keys for identifying tree species or other forest details have been used in Australia and to a lesser degree in North America. They have proven most useful where photography has been taken to uniform specifications over rather large areas.

4 - Relatively simple and inexpensive devices are used for making most photo measurements or estimates needed for forest photo interpretation. For example, parallax wedges and parallax bars (or stereometers) used under lens stereoscopes serve essentially as well as elaborate stereo plotters for making measurements of images of tree or stand heights. Other commonly used aids for interpretation of temperate forests are dot grids for estimating areas, and scales for estimating crown coverage or density, and crown diameter. Crown diameter scales are also used to some degree for photo interpretation of tropical forests.

C - Photo Interpretation and associated techniques

1 - Sampling designs involving photo plots may be systematic (used in most inventories in the United States and in management inventories in Canada) or random (generally used in Australia and in regional inventories in Canada). Usually templets indicating the desired spacing of plots and desired shape and size of each plot are overlaid on photos.

Interpretation of photo plots provides forest classification which may be used to stratify field plots by gross volume (often used in North America) or by another significant variable such as broad cover type classes (used in Thailand 5/).

Sequential photo sampling (i.e., repeated photo coverages of the same plots) is used in Canada and in the United States on some continuous inventories (re-inventories at rather frequent intervals) together with remeasurements of permanent field plots. This procedure, giving direct comparisons of photo images taken several years apart, is particularly useful in determining changes in the forest due to growth and drain.

Double sampling (paired observations and measurements made on photo and field plots centered over the same ground area) is an efficient procedure for adjusting and refining estimates made by a large number of photo plots and is used in several regional inventories in North America.

The usual size of photo plot is such as to cover no more than one acre of ground area. When scale of photography is fairly large -- in excess of 1:10,000 -- photo plots may be used covering a ground area as small as one-fifth acre. A circular plot has generally been the most convenient shape to use. In all inventory applications where field estimates are used to adjust photo estimates, the photo and field plots should be designed to sample approximately the same ground area. For example, with photography of large timber at a scale of 1:15,840, the smallest desirable photo plot might be one representing one-half acre. If variable-radius circular field plots (angle-gauge or point samples) are desired, one of these may be centered on the point forming the center of a one-half acre circular photo plot or a cluster of several field plots may be centered around the same point.

Field plots generally used to sample stand classes stratified by photo interpretation are: in Canada, 1/5- or 3/10-acre rectangular plots or clusters of four 1/10 acre circular plots; in Australia, 1-acre rectangular plots for indigenous forests and 1/10- or 1/5-acre plots or angle-gauge samples for exotic plantations; in the United States, 1/4- or 1/5-acre circular plots or angle-gauge samples of the basal area factor appropriate to the forest type. In some inventories of tropical forests clusters of small circular plots (of less than 1/5-acre) have been recommended. For example, in an inventory of Thailand concentric plots of 0,01ha and 0,05ha arranged along lines forming a large rectangle; or "tract", were used.5/ In other surveys in the tropics sampling strips (with 100 percent enumeration of most valuable stands) have been used.4/

2 - Photo interpretation of the following information is done with accuracies that vary with quality of the photography, the complexity of the forests and

the experience of the interpreter: land use class, tree species, forest cover type, physiographic site, stand-volume and stand-age classes and damage or infestation classes (caused by such agent as forest insects, diseases and fires). Interpretation of such items is generally proving to be more difficult on photos of tropical forests than on photos of temperate forests.

3 - Photo measurements or estimates of the following items of information are feasible using the techniques indicated:

Distances are measured using Engineer's scales graduated either in 50ths or 100ths of an inch. Short distances are also measured with micrometer line wedges graduated in 100ths of an inch. Transparent conversion scales or wedges are also used. These permit readings on photos directly in equivalent ground survey units (e.g. in chains or feet) for each scale in a range of scales of photography.

Angles are measured between images on photos (to determine directions between objects on the ground) by using transparent photo protractors graduated in degrees. To minimize errors caused by relief displacements in mountainous areas, a base line for turning an angle is selected that lies essentially in the same datum as that of the point to which a bearing is sought. The base line is also preferably chosen to be reasonably close to the point in question and near the center of the photograph.

Areas of forest classes are measured generally by intensive dot counts, square counts or line transects, using templets overlaid on photos or on maps to which boundaries of areas delineated on photos have been transferred. Although the polar planimeter is also used for measuring areas shown on maps the relatively small gains in accuracy by this laborious method over methods mentioned above are not considered sufficient to justify its use for most forestry purposes. Sampling with photo plot templets directly on photographs is also used for estimating areas when forest classes are not delineated. This procedure gives reasonably accurate results even on photos of areas of high relief when precautions are taken to minimize bias due to variations in scale of photography.

Slopes of terrain are usually determined by measuring parallax differences with a parallax wedge, stereometer or stereoplotting instrument. Sometimes a slope percent scale is used to convert elevation differences into slope percent without computation.

Crown closure is generally estimated ocularly in percent classes with occasional checks made by comparing images of stands with crown density scales (estimating guides). Greater use of measurements of crown closure by such devices as intensive dot grids and line transects is recommended.

Tree and stand heights are determined generally by parallax measurements made with parallax wedges, stereometers or parallax bars; occasionally they are determined from measurements of shadows or displacements of single images made with micrometer wedges.

Tree crown diameters are measured either with micrometer (line) wedges or dot-type wedges.

4 - Transfer of delineations from photos to base maps is usually by such instruments as sketchmaster, multiscope, stereotope, stereomicrometer or radial-line plotter.

D - Photo interpreters

a - Selection of interpreters is generally on an informal basis although increasing numbers of recruits are selected from forest school graduates who have had courses in photo interpretation. Some agencies (including government departments in Australia) give stereovision tests and related tests of PI aptitude as a partial basis for selection.7/ 8/

7/ Sims, W. G. & Hall, N. THE TESTING OF CANDIDATES FOR TRAINING AS AIR PHOTO INTERPRETERS. Forestry & Timber Bureau, A.C.T. 1956.

8/ Lawrence, P. R. TESTING THE EFFICIENCY OF PHOTO-INTERPRETATION AS AN AID TO FOREST INVENTORY, 7th British Commonwealth Forestry Conference 1957.

b - Training of most interpreters is on-the-job although a number of forest schools -- in Canada, the United States and Australia -- give regular courses and intensive short courses in photo interpretation and photogrammetry. The International Training Centre for Aerial Survey at Delft, The Netherlands, also gives a course in forest photo interpretation.

E - Visual reconnaissance to check PI.

Field observations to verify or correct forest photo interpretation are generally made on the ground, often during the course of travel between field plots. Visual checks from low-flying and slow-moving aircraft have also been effective in Canada and other areas, particularly to check land-use class, cover type, and species composition. Visual checks of stand sizes or tree sizes are not as effective from moving aircraft. Careful planning is essential for efficient visual checking regardless of the mode of travel.

F - General inventory designs using aerial applications to aid in determining areas of forest classes and volumes, growth and drain of timber.

1 - Double sampling by photo and field plots to estimate all statistics.

(1) Photo plots systematically located over aerial photos are interpreted to provide area estimates of land-use and forest condition classes and to provide a basis for stratifying field plots by gross volume or other class. (2) A relatively small number of field plots is randomly or systematically selected from the photo plots falling on forest land. Estimates are made on all field plots to determine details of forest classes and timber and these data are used to adjust estimates made by photo plots and to provide estimates of other items such as detail on quality, defect and mortality of the timber not obtainable by photo interpretation.

Double sampling as applied to human populations was described by Neyman in 1938 9/. The application to tree populations was described by Bickford

---

9/ Neyman, J. Contributions to theory of sampling human populations. JOURNAL OF AMERICAN STATISTICAL ASSOCIATION, 33:101-116, 1938.

in 1952 10/. The method as applied to forest inventories is described in several books. THE MANUAL OF PHOTO INTERPRETATION 11/- gives procedures for determining optimum relative numbers of photo and field plots to be taken. Procedures for adjusting photo estimates by field estimates are also given in the same publication, and are discussed briefly in Section 19 of the FORESTRY HANDBOOK 12/and in Chapter 26 of Spurr's FOREST INVENTORY 13/. The design permits rapid inventories at reasonable costs and computation of confidence limits for statistics, although the planning and computing phases are rather complicated. It is used in parts of the United States and Canada on regional inventories.

2 - Triple sampling by photo and field plots to estimate all statistics.

(1) Photo plots (located as in double sampling) are interpreted to provide area estimates of land-use classes. (2) A portion of those photo plots falling on forest land is interpreted to provide estimates of forest condition classes and to stratify field plots. (3) Field plots are selected from the photo plots interpreted in Step 2, and data from these are used as in double sampling.

References for and utility of this design are the same as those for double sampling. The design is used in parts of the United States on regional inventories.

10/ Bickford, C. A. The sampling design used in the forest survey of the northeast. JOURNAL OF FORESTRY, 50:290-292, 1952.

11/ American Society of Photogrammetry, 1960. MANUAL OF PHOTO INTERPRETATION, George Banta Publishing Co., Menasha, Wisconsin.

12/ Society of American Foresters, 1955. FORESTRY HANDBOOK. The Ronald Press Co., New York.

3 - Photo sampling to estimate land-use classes and field sampling to estimate all other statistics.

(1) As in triple sampling, numerous photo plots are taken to obtain a preliminary estimate of land-use classes. (2) Field plots are taken in a random or systematic manner from the photo plots falling on forest land, and these are used to adjust photo estimates of land-use classes and provide estimates of all other statistics.

References are the FORESTRY HANDBOOK 12/, the MANUAL OF PHOTO INTERPRETATION 11/ and FOREST INVENTORY 13/. The design is relatively simple, reasonably flexible and is dependable. It tends to be somewhat more costly and slower in operation than the double and triple sampling desings. It is used on some regional and management inventories in the United States.

4 - Photo mapping to determine areas of forest classes and sampling to estimate other statistics.

(1) Forest condition classes are interpreted and delineated on aerial photos and are checked in the field as necessary. Delineations are transferred to base maps and areas of forest classes are determined by planimetry of all mapped units (or by other method of determining areas on maps, such as intensive dot counts). (2) Field plots are generally taken in a random or systematic manner to provide representative samples of each forest class. The data from field plots are the bases for estimating such statistics as species composition, volume and mortality in each forest class. Variations of the design include the empirical selection of locations for field plots, or ocular estimates of "average" statistics for each class and estimates of "averages" derived by photo interpretation.

The design is referred to in various articles and books including the MANUAL OF PHOTO INTERPRETATION11/, the FORESTRY HANDBOOK 12/, FOREST INVENTORY 13/, and

---

13/ Spurr, Stephen H. 1952. FOREST INVENTORY. The Ronald Press Co., New York.

PHOTOGRAMMETRY AND PHOTO-INTERPRETATION [14]. It produces a useful map of forest conditions as an integral part of the procedures, but is more costly than the previous designs. Confidence limits cannot be computed as easily as under the previous designs; accuracy of delineation varies with subjective decisions of photo interpreters and field mappers as they judge the "average" of rather wide ranges in conditions over rather large areas. This contrasts with the greater accuracy of determinations made in classifying small sample plots where the range in conditions is more limited. The design is used on management inventories in North America and in the tropics. A variation used in central Europe is aimed primarily to produce a forest map by photo interpretation and field checking for use in management planning. Ocular estimates of timber volume are made, which are checked by angle-gauge samples occasionally.

Conclusions

A major purpose of preparing and distributing this preliminary progress report is to invite suggestions for additions to these lists. In a subsequent report the committee plans to evaluate its findings and present recommendations (or at least separate listings) for procedures which apparently have rather widespread, if not universal, applications. At the same time attention will be directed to those procedures which appear to be considerably more limited in application -- perhaps to some which may be very effective in particular situations and ineffective in most if not all other situations. As an example, on the basis of evidence now available to the committee, it appears that some of the applications of aerial photography and photo interpretation which have proven successful for inventories of forests in temperate zones do not appear to be effective for inventories of tropical rain forests. Thus, the committee invites comments which will help to appraise the relative suitability of an application in certain geographic areas or for certain inventory purposes, such as for reconnaissance, regional planning or management planning on individual properties. Suggestions are also invited for needed research studies to increase the efficiency of applying aerial photography to forest inventories. Suggestions and comments may be sent to

[14] Spurr, Stephen H. 1952. FOREST INVENTORY. The Ronald Press Co., New York.

any member of the IUFRO Committee on the use of aerial photographs in forest inventories listed below:

Dr. D. A. Boon
International Training Center
for Aerial Survey
Delft 3
Kanaalweg, Holland

Ing. Vladimir Cermak
Forest Research Institute
Banska Stiavnica Sub-Office
Bratislava
Michalska 24/11
Czechoslovakia

Dr. D. A. N. Cromer
Division of Forest Management
Research
Forestry and Timber Bureau
Canberra, Australia

Dr. F. Loetsch
Federal Forest Research
Institute
Linden strasse 21
Reinbek, Hamburg, Germany

Mr. Robert G. Miller
Forestry and Land Use Section
Directorate of Overseas Surveys
Kingston Road
Tolworth, Surbiton
Surrey, England

Mr. H. Reichardt
Forestry Division
Food and Agriculture
Organization of the
United Nations
Viale delle Terme di
Caracella
Rome, Italy

Prof. J. H. G. Smith
The University of British
Columbia
Faculty of Forestry
Vancouver 8, B. C., Canada

Mr. R. C. Wilson (Chairman
of Committee)
Forest Survey Branch
U. S. Forest Service
Washington 25, D. C., U.S.A.